MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2015/2016

ETN2016 – ANALOG COMMUNICATIONS

(All Section / Groups)

7 MARCH 2016
9:00 AM – 11:00 AM
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of 7 pages (including this cover page) with 4 Questions only and an appendix.

2. Attempt **ALL** questions. All questions carry equal marks and the distribution of the marks for each question is given.

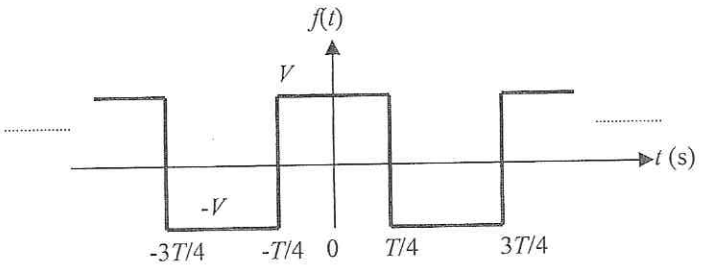
3. Please print all your answers in the Answer Booklet provided.

Question 1

(a) (i) Describe the differences between analog and digital communication systems. [6 marks]

(ii) Differentiate between Frequency Modulation (FM) and Frequency Shift Keying (FSK). [2 marks]

(b)



The figure above shows a periodical waveform that alternates between variable magnitudes of $+V$ and $-V$. It can be expressed in the form of trigonometric Fourier series as follows:

$$f(t) = A_0 + \sum_{n=1}^{\infty} A_n \cos\left(\frac{2\pi nt}{T}\right) + \sum_{n=1}^{\infty} B_n \sin\left(\frac{2\pi nt}{T}\right)$$

where

$$A_0 = \frac{1}{T}\int_{-\frac{T}{2}}^{\frac{T}{2}} f(t)\ dt$$

$$A_n = \frac{2}{T}\int_{-\frac{T}{2}}^{\frac{T}{2}} f(t)\cos\left(\frac{2\pi nt}{T}\right) dt$$

$$B_n = \frac{2}{T}\int_{-\frac{T}{2}}^{\frac{T}{2}} f(t)\sin\left(\frac{2\pi nt}{T}\right) dt$$

T is the period of the waveform.

(i) Suppose $T = 2$ s. Find A_0, A_n, and B_n. Give their values for $n = 1, 2, 3, 4, 5, 6$. [6 marks]

(ii) Express $f(t)$ by expanding the summation series. [2 marks]

Continued ...

Question 1 (continued)

(c) The Fourier transform of $x(t)$ is given by $X(f) = \dfrac{j2\pi f}{1+j2\pi f}$. Find $Y(f)$, the Fourier transform of $y(t)$ for the followings:

(i) $y(t) = e^{-jt}x(t-1)$

(ii) $y(t) = x(2t)$

(iii) $y(t) = x'(t)$

[9 marks]

Question 2

(a) In the design of a transmitter that generates amplitude modulated (AM) wave, you are given two signals, i.e. the message signal $m(t) = \mathbf{37.5}\cos[(2\pi)(\mathbf{10}\times\mathbf{10}^3 t)]$ volts, and the carrier wave $c(t) = \mathbf{100}\cos[(2\pi)(\mathbf{500}\times\mathbf{10}^3 t)]$ volts. Suppose an AM wave of **75%** modulation is generated.

(i) Find the power developed across a load of **100** ohms due to this AM wave.

[2 marks]

(ii) Find the power contained in the **carrier** and in the **sidebands**.

[4 marks]

(iii) Sketch the power spectrum of the AM wave.

[6 marks]

(b) Suppose a message signal is given as $m(t) = A_m\cos(2\pi f_m t)$ volts, and the carrier wave is given as $c(t) = A_c\cos(2\pi f_c t)$ volts. They are used to generate a conventional AM wave, also known as the Double Sidebands Large Carrier (DSB-LC) wave. The DSB-LC wave is filtered by a narrowband filter centered at frequency f_c+f_m, before being supplied to a load of R ohms.

(i) Derive the expression for the modulated signal **before** and **after** the filtering process.

[6 marks]

(ii) The product after the filtering process is also a type of AM wave. What do we call it?

[1 mark]

(iii) Determine the power of the modulated signal **before** the filtering process.

[3 marks]

(iv) Determine the power of the modulated signal **after** the filtering process.

[3 marks]

Continued ...

Question 3

(a) Consider a FM signal that is expressed as follows:

$$x(t) = A\cos\left[2\pi f_c t + B\int_0^t \cos\left(2\pi f_m \tau\right)d\tau\right]$$

where A and B are constants.

Write down the following expressions:

(i) Message signal, $m(t)$

(ii) Instantaneous phase deviation, $\Delta\theta_i(t)$ [integration must be solved]

(iii) Instantaneous phase, $\theta_i(t)$ [integration must be solved]

(iv) Angular frequency deviation, $d\,[\Delta\theta_i(t)]\,/dt$

(v) Instantaneous angular frequency, $\omega_i(t)$

(vi) Instantaneous frequency, $f_i(t)$

(vii) Instantaneous frequency deviation, $\Delta f_i(t)$

(viii) Modulation index, β

[8×2 = 16 marks]

(b) A receiver picks up a frequency modulated (FM) signal that is expressed as follows:

$$x(t) = \mathbf{10}\cos\{\,(2\pi)(6\times10^6\,t) + \mathbf{2}\sin[(2\pi)(3\times10^4\,t)]\,\}$$

(i) Calculate the average total power of the FM signal, P_{total}.

[2 marks]

(ii) Find the carrier's power. Make use of the Table of Bessel Function of the First Kind provided below.

[3 marks]

(iii) Find $P_{sidebands}$, the amount of transmission power that falls within the significant **sidebands**, excluding the carrier's power.

[4 marks]

Table of Bessel Function of the First Kind

	$J_n(\beta)$							
n	$\beta = 0.2$	$\beta = 0.3$	$\beta = 0.5$	$\beta = 0.7$	$\beta = 1.0$	$\beta = 2.0$	$\beta = 3.0$	$\beta = 5.0$
0	0.990	0.978	0.938	0.881	0.765	0.224	-0.260	-0.178
1	0.100	0.148	0.242	0.329	0.440	0.577	0.339	-0.328
2	0.005	0.011	0.031	0.059	0.115	0.353	0.486	0.047
3		0.001	0.003	0.007	0.020	0.129	0.309	0.365
4				0.001	0.002	0.034	0.132	0.391
5						0.007	0.043	0.261
6						0.001	0.011	0.131
7							0.003	0.053
8								0.018
9								0.006
10								0.001

Continued ...

Question 4

(a) A superheterodyne FM receiver has an intermediate frequency (IF) of 455 kHz. The frequency down-conversion is done with **high-side** local oscillator (LO) injection. Determine the followings when the receiver is tuned to a station at 3640 kHz.

(i) LO frequency.

[2 marks]

(ii) Image frequency.

[2 marks]

(iii) Image rejection ratio if the image rejection filter consists of a tuned circuit with quality (Q) factor of 20.

[3 marks]

(iv) Repeat the above calculations, i.e. parts (i), (ii), and (iii), for **low-side** LO injection.

[7 marks]

(b) Envelope detection is performed on an amplitude-modulated (AM) signal using the structure depicted in Fig. Q4.1. The input to the envelope detector is given by $x(t) = s(t) + n(t)$, where $n(t)$ represents the noise. The AM signal is represented by

$$s(t) = A_c\,[1 + k_a m(t)]\cos(2\pi f_c t)$$

where $A_c\cos(2\pi f_c t)$ is the carrier wave, $m(t)$ is the message signal, and k_a is the amplitude sensitivity of the modulator.

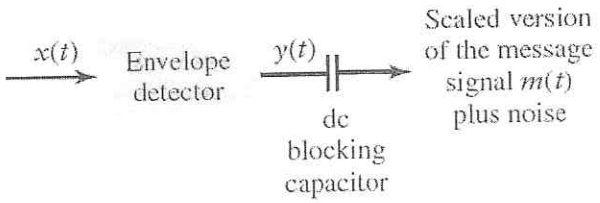


Fig. Q4.1 Model of AM receiver using envelope detection

Evaluate the performance of the envelope detector in the presence of noise by deriving an expression for the signal-to-noise ratio, SNR.

[11 marks]

End of Questions

APPENDIX

Fourier Transform Pairs

$x(t)$	$X(f)$
$\delta(t)$	1
$\delta(t-t_o)$	$e^{-j2\pi ft_o}$
1	$\delta(f)$
$e^{j2\pi f_o t}$	$\delta(f-f_o)$
$u(t)$	$\frac{1}{2}\delta(f)+\frac{1}{j2\pi f}$
$e^{-at}u(t)$	$\frac{1}{a+j2\pi f}$, for $a>0$
$e^{at}u(-t)$	$\frac{1}{a-j2\pi f}$, for $a>0$
$e^{-a\lvert t\rvert}$	$\frac{2a}{a^2+(2\pi f)^2}$, for $a>0$
$rect\left(\frac{t}{T}\right)$	$T\text{sinc}(fT)$
$\text{sinc}(2Wt)$	$\frac{1}{2W}rect\left(\frac{f}{2W}\right)$
$\Delta\left(\frac{t}{T}\right)$	$\frac{T}{2}\text{sinc}^2\left(\frac{fT}{2}\right)$
$W\text{sinc}^2(Wt)$	$\Delta\left(\frac{f}{2W}\right)$
$e^{-\pi t^2}$	$e^{-\pi f^2}$
$\cos(2\pi f_o t)$	$\frac{1}{2}\delta(f-f_o)+\frac{1}{2}\delta(f+f_o)$
$\sin(2\pi f_o t)$	$\frac{1}{2j}[\delta(f-f_o)-\delta(f+f_o)]$

Fourier Transform Properties

Let $x(t) \Leftrightarrow X(f)$, $x_1(t) \Leftrightarrow X_1(f)$ and $x_2(t) \Leftrightarrow X_2(f)$; and a, b, t_o and f_o scalar quantities.	
Linearity	$ax_1(t)+bx_2(t) \Leftrightarrow aX_1(f)+bX_2(f)$
Scaling ($a \neq 0$)	$x(at) \Leftrightarrow \frac{1}{\lvert a \rvert} X\left(\frac{f}{a}\right)$
Time Shifting	$x(t-t_o) \Leftrightarrow X(f)e^{-j2\pi f t_o}$
Frequency Shifting	$x(t)e^{j2\pi f_o t} \Leftrightarrow X(f-f_o)$
Time Convolution	$x_1(t) * x_2(t) \Leftrightarrow X_1(f)X_2(f)$
Frequency Convolution	$x_1(t)x_2(t) \Leftrightarrow X_1(f) * X_2(f)$
Time Differentiation	$\frac{d^n}{dt^n} x(t) \Leftrightarrow (j2\pi f)^n X(f)$
Frequency Differentiation	$(-jt)^n x(t) \Leftrightarrow \frac{d^n}{df^n} X(f)$
Time Integration	$\int_{-\infty}^{t} x(\tilde{t})d\tilde{t} \Leftrightarrow \frac{X(f)}{j2\pi f} + \frac{1}{2}X(0)\delta(f)$
Frequency Integration	$x(t)u(t) \Leftrightarrow \int_{-\infty}^{f} X(\tilde{f})d\tilde{f}$

Useful Trigonometric Identities

$$\sin A \sin B = \frac{1}{2}\left[\cos(A-B) - \cos(A+B)\right]$$

$$\cos A \cos B = \frac{1}{2}\left[\cos(A+B) + \cos(A-B)\right]$$

$$\sin(A+B) = \sin A \cos B + \cos A \sin B$$

$$\cos(A+B) = \cos A \cos B - \sin A \sin B$$

$$\sin\theta = \frac{1}{2j}\left[e^{j\theta} - e^{-j\theta}\right]$$

$$\cos\theta = \frac{1}{2}\left[e^{j\theta} + e^{-j\theta}\right]$$

End of Paper